

Correlation of PaCo₂ and EtCo₂ in Neurology Patients Who are Mechanically Ventilated in Intensive Care Unit

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Abstract:

Background: Monitoring arterial partial pressure of carbon dioxide (PaCO₂) is crucial in neurology patients because it has a direct impact on intracranial pressure (ICP), cerebral blood flow, volume, and cerebral perfusion pressure (CPP). Hence, continuous monitoring of CO₂ is crucial. Another method for continuous and non-invasive estimation of CO₂ is through measuring end-tidal CO₂ (ETCO₂). **Aim and objective:** To correlate the PaCo₂ and EtCo₂ values among neurology patients who are mechanically ventilated in an Intensive Care Unit. **Materials and methods:** An Analytical Cross-sectional Correlation study carried out in ICU for a 1-year duration on 30 neurology mechanically ventilated patients above 18 years of age who don't have cardiac disorders and pulmonary hypertension were included. Etco₂ from the multipara monitor was noted and PaCo₂ from ABG was also noted at the same time. Data analysis was done using SPSS software version 25. **Result:** The study showed an age range from 21 to 85 years with a median age of 41.5 years and a gender distribution of males (70%) more than females (30%). The prevalence of neurological disorders was found as most at Subarachnoid haemorrhage (33.3%) and the least Traumatic brain injury (6.7%). There was a statistically significant correlation between PaCO₂ and ETCO₂ with Pearson's correlation coefficients of 0.6053 and p-value <0.05. **Conclusion:** The correlation between ETCO₂ and PaCO₂ suggests that non-invasive end-tidal CO₂ might be a useful proxy for invasive arterial PaCO₂ in neurology mechanical ventilated patients for monitoring the CO₂ levels. **Keywords:** ETCO₂, mechanically ventilated, Neurology, PaCO₂.

Introduction:

In neurology, monitoring the arterial partial pressure of carbon dioxide (PaCO₂) in patients is crucial because it influences intracranial pressure (ICP), cerebral blood flow, volume, and cerebral perfusion pressure (CPP). An increase in PaCO₂ raises ICP, which in turn reduces CPP. Both PaCO₂ and end-tidal carbon dioxide (ETCO₂) serve as indicators of ventilatory adequacy. Understanding PaCO₂ levels in neurology patients is essential due to their impact on cerebral blood flow. ETCO₂ has been utilized as a non-invasive estimate of PaCO₂.^[1] The typical difference between PaCO₂ and ETCO₂ in healthy, alert individuals ranges from 3.6 to 4.6 mmHg.^[2] Recent anaesthetic literature has raised some debate regarding the accuracy of end-tidal CO₂ (ETCO₂) as a reflection of PaCO₂.^[3,4] Capnography has become a recognized standard for the monitoring of mechanically ventilated patients and is commonly employed during the ventilation of critically ill patients experiencing respiratory failure.^[5] The

assessment of respiratory rate, ETCO₂, and the morphology of the respiratory waveform aids in determining the presence of respiratory distress, ventilatory adequacy, and bronchial obstruction. Clinically, ETCO₂ serves as a positive sign of successful endotracheal intubation, alerts for disconnection, and estimates PaCO₂. Capnography, which involves measuring end-tidal carbon dioxide (ETCO₂), is an established technique for monitoring respiratory function during routine anesthesia procedures.^[6] ETCO₂ indicates the partial pressure of carbon dioxide at the end of expiration and reflects the arterial carbon dioxide tension (PaCO₂). One treatment approach utilized by anesthesiologists to manage elevated intracranial pressure (ICP) in neurosurgical patients is hyperventilation, which decreases arterial PaCO₂; this method is effective only when the cerebral vasculature's reactivity to PaCO₂ is normal and intact.^[7] It is well understood that PaCO₂ has an inverse correlation with cerebral arterial resistance.^[8] Therefore, anesthesiologists must be knowledgeable about PaCO₂ and ETCO₂ levels in situations where elevated ICP may be a concern.^[9] This study aims to evaluate our standard practice of obtaining PaCO₂ in neurology patients on mechanical ventilation while comparing it with simultaneous ETCO₂ measurements. The goal is to assess whether ETCO₂ accurately reflects PaCO₂ within acceptable limits.

Methodology

After getting approval from the Institute's Ethical Committee, this study was carried out at the Intensive Care Unit of Dr. Vithalrao Vikhe Patil Pravara Rural Hospital, Loni. This Analytical Cross-sectional Correlation study was carried out in ICU for a 1-year duration on 30 neurology mechanically ventilated patients above 18 years of age. Demographic information such as age, gender and history, vital signs (pulse, blood pressure, respiratory rate), and fingertip oxygen saturation (SpO₂), will be noted in the patients who met the inclusion criteria that is Relatives willing to give consent to participate in this study, all patients above the age of 18 years and in Invasive Mechanical Ventilation support, Patients of either gender, All patients admitted in Invasive Care Unit. And the exclusion criteria were Patients who are known cases of cardiac disorders, Patients who have pulmonary hypertension, Patients on Non-invasive Mechanical Ventilation and Patients who are hypotensive and are receiving Inotropic support

The PaCO₂ and EtCO₂ values will be measured in the blood gas after the IMV application is started. A mainstream capnograph (Dräger Oxi plus) was placed between the connection of the mask and the hose, and EtCO₂ was measured. Arterial blood gas samples were taken from the patients at the same time. Testing of the samples was performed with the calibrated ABL800 FLEX © blood gas analyzer (ABL800) and the PaCO₂ value was recorded. All the data from the study proforma of individual study subject entered, compiled in Microsoft office excel sheet. Appropriate statistical tests were used to study the result outcomes.

Statistical analysis: We calculated sample size with the reference of Gaur P, Harde M, Gujjar P, Deosarkar D, Bhadade R. A study of partial pressure of arterial carbon dioxide and end-tidal carbon dioxide correlation in the intraoperative and postoperative period in neurosurgical patients. *Asian J Neurosurg* 2017;12:475-82 article the correlation coefficient was taken as 0.79 and the calculated sample size was 16. (Fig 1)

We opted for a sample size of 30, deemed appropriate for both the study design and the institutional circumstances.

Sample size for Correlation Coefficient-r			
Note: Enter values in YELLOW cells only. Values in RED cells will be calculated by the system.			
N	Guestimate of Correlation coefficient	0.79	
Cr	Fisher's arctanh transformation	1.071432	Source
1-α	Set level of confidence (<1.0)	0.99	http://www.cct.cuhk.edu.hk/stat/other/correlation.htm
1-β	Set level of power of test (<1.0)	0.9	http://www.statsdirect.com/help/default.htm#sample_size/correlation.htm
Z1	Z value associated with alpha	2.575829	$n = \frac{((Z1+Z2)/Cr)^2}{}$
Z2	Z value associated with beta	1.281552	$Cr = \frac{1}{2} \{ \text{LOGe} \frac{(1+r)}{(1-r)} \}$
n	Minimum Sample size	16	
Z'r1		1.071432	Prepared by: Dr. A.P. Kulkarni
Z'r0		0	drapkulkarni@gmail.com
n	Minimum sample size	16	Mobile: 9422701650

Fig 1: Sample size calculation

Quantitative data are presented with the help of mean, median, standard deviation (SD), minimum and maximum values. Qualitative data are presented with the help of frequency and percentage table. Data were initially analyzed using Pearson’s correlation to assess the relationship between PaCO2 and ETCO2 . P < 0.05 was considered statistically significant with 95% confidence interval (CI). Analysis was done using IBM SPSS (SPSS Inc., IBM Corporation, NY, USA) statistics Version 25 for Windows software program.

Results:

A total of 30 sample size was collected, in which 21 patients were male (70%) and 9 were female (30%). The minimum age was 21 years and maximum was 85 hears old with maximum patients fall in 20 to 29 range age group and the median age is 41.5 years. The indications for mechanical ventilation was noted as Poor GCS 23(76.6%) , not maintaining saturation 1 (3.3%), both poor GCS and not maintaining saturation 5 (16.6%) and post operative 1(3.3%). The prevalence of nuerological disorders that got mechanical ventilation during the study noted as Subarachnoid Hemorrhage (SAH): 10 cases (33.3%) ,Cerebrovascular Accident (CVA) / Stroke: 6 cases (20%) ,Epidural Hematoma (EDH): 3 cases (10%), Intracerebral Hemorrhage (ICH): 3 cases (10%),Infarct: 3 cases (10%),Traumatic Brain Injury (TBI): 2 cases (6.7%) Others (one case each): 10% (Frontotemporal contusion, Cervical vertebrae fracture, Diffuse axonal injury, Generalized cerebral edema). From descriptive statistics EtCO2 mean value noted as 33.52 with median 34 and standard deviation 4.68 and PaCO2 mean noted as 35.65 with median 36 and standard deviation 6.30. From the total 30 sample size collected, The relationship between the variables EtCO2 and PaCO2 using Pearson’s correlation, a favourable association was found in the study, r= 0.6053 (P<0.001) This indicates a positive correlation between the two variables. The scatter plot visually represents the relationship between ETCO2 and PaCO2. Each point on the plot represents a pair of ETCO2 and PaCO2 measurements from a patient. (X axis EtCO2 and Y axis PaCO2)

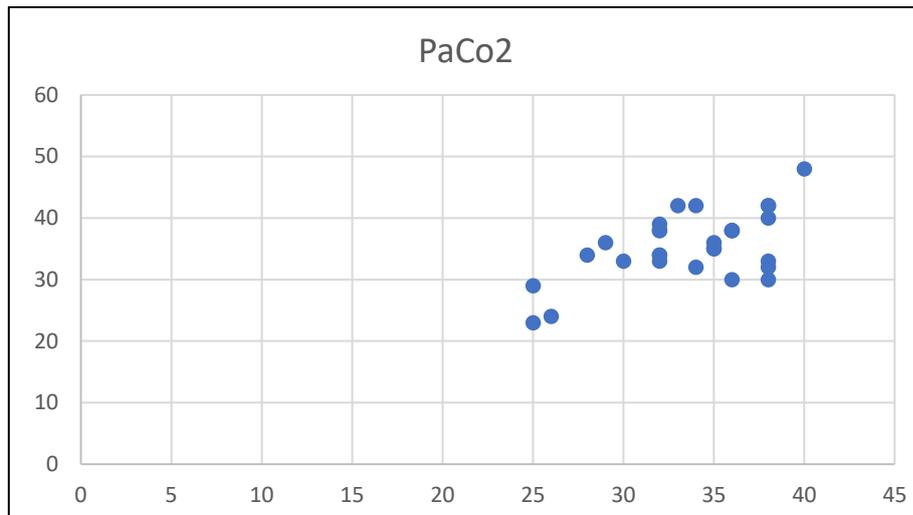


Fig 2: Scatter plot of PaCo2 and EtCo2

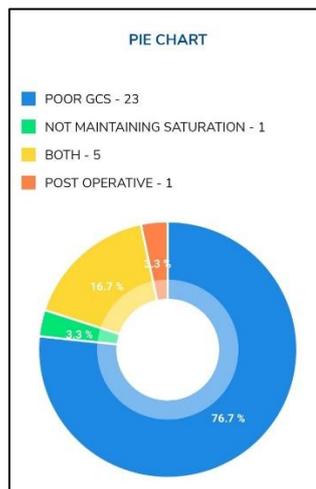


Fig 3: Pie chart showing indications for mechanical ventilation

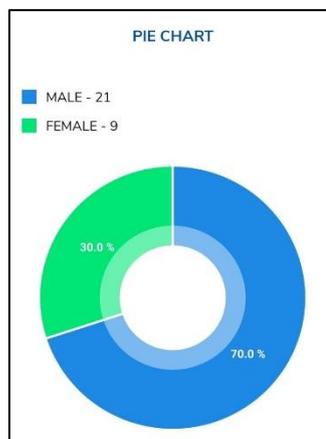


Fig 4: Pie chart showing sex distribution

Discussion:

The relation between end-tidal carbon dioxide and arterial carbon dioxide partial pressure is a significant factor in managing neurology patients on mechanical ventilation. End-tidal carbon dioxide serves as a non-invasive indicator of the partial pressure of carbon dioxide at the end of the expiratory phase, while PaCO₂ refers to the arterial partial pressure of carbon dioxide determined through blood gas analysis. Measuring arterial blood gases to determine PaCO₂ is considered the gold standard for tracking fluctuations in blood carbon dioxide, though it is invasive, costly, and gives only sporadic readings of PaCO₂. In contrast, ETCO₂ allows for ongoing respiratory monitoring of fluctuations in blood carbon dioxide levels. This investigation was conducted on 30 neurology patients aged between 18 and 85 years who were being mechanically ventilated, focusing on the correlation between PaCO₂ and ETCO₂.

In the context of mechanical ventilation, it is vital to track both Etco₂ and PaCO₂ to maintain adequate ventilation and gas exchange. Hypercapnic acidosis, characterized by elevated PaCO₂, can result from lung damage or respiratory failure and may be observed in patients receiving mechanical ventilation. Monitoring Etco₂ provides a continuous and immediate evaluation of ventilatory status, facilitating the early identification of shifts in PaCO₂ levels. Several research studies have investigated the relationship between Etco₂ and PaCO₂ with the objective of determining how Etco₂ can be utilized to approximate PaCO₂ and assist in ventilator management. [12,13]

Kerr et al. 1996 studied the relationship between PaCO₂ and ETCO₂ in mechanically ventilated adults with severe head trauma and also observed ETCO₂ monitoring correlating well with PaCO₂ in patients without respiratory complications or without spontaneous breathing.^[10] Razi et al. 2012, in healthy subjects there are close correlation between PaCO₂ and ETCO₂, and it is commonly accepted that PaCO₂ measurements vary approximately 2–5 mmHg above ETCO₂ values.^[11]

In our study subarachnoid hemorrhage (SAH) was the most common diagnosis (33.3%), followed by cerebrovascular accident (CVA)/stroke (20%). Sex Distribution Males accounted for 70% of cases, while females accounted for 30%. Age Distribution, The Mean age was 41.5 years, with a range of 21-85 years. Mechanical Ventilation Indications: Poor Glasgow Coma Scale (GCS) was the primary indication (76.7%). Ventilation Mode: Volume control was the dominant mode (96.7%). Our study showed that ETCO₂ is a measure of PaCO₂ in neurology mechanical ventilated patients, which was consistent with the studies mentioned above. This study observed a statistically significant correlation ($r = 0.6053$, $p < 0.05$) between PaCO₂ and ETCO₂ levels. Both ETCO₂ and PaCO₂ levels showed similar trends, with means of 33.52 and 35.65, respectively. Standard deviations of 4.68 (ETCO₂) and 6.30 (PaCO₂) indicate variability in carbon dioxide levels. Thus, we conclude that the End-tidal Carbon dioxide (ETCO₂) reflects the Arterial partial pressure of Carbon dioxide (PaCO₂) with a statistically significant accuracy and hence can be used as a measure for PaCO₂.

Conclusion:

This study indicates that ETCO₂ accurately reflects PaCO₂ within acceptable limits. This correlation is particularly strong in patients who are hemodynamically stable and have healthy

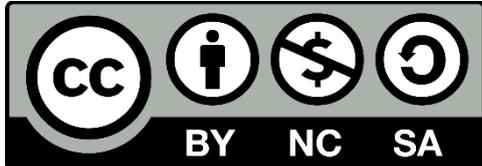
lungs. Therefore, the simple, continuous, and non-invasive measurement of ETCO₂ can serve as a dependable means to estimate PaCO₂ in mechanically ventilated neurology patients in critical care settings. The relationship between ETCO₂ and PaCO₂ implies that non-invasive end-tidal CO₂ may effectively serve as an alternative to invasive arterial PaCO₂ for monitoring CO₂ levels in neurology patients on mechanical ventilation.

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Source of funding: Nil

Conflict of interest: Nil



Submitted: 08/01/2025

Revised: 16/02/2025

Accepted: 28/05/2025

Published: 30/06/2025

Cite this article:

Dr. Haripriya U S, Dr. Akshaya N Shetti. Correlation of PaCo₂ and EtCo₂ in neurology patients who are mechanically ventilated in intensive care unit. Jour Med Dent Fron 2025;2(1):63 - 69